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RELATIONSHIPS OF HOURLY DURATIONS TO THE
DAILY MAXIMUM TEMPERATURE

by

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FOREWORD

This report was prepared under Project 1T025001A129, Geographic Research, Task 03, Methods for Predicting Environmental Conditions. Work in this area is directed toward the development of methods for making accurate and complete working estimates of natural environments and the probable resulting stress on men and materiel in any terrain or season throughout the world.

Under this task a nomogram has been developed for estimating probable longest temperature durations, using only the absolute maximum and minimum temperature of the month and the resultant range. The durations included in this report for hot summer days may be useful in developing a correction factor to the nomogram.

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ABSTRACT

Durations of temperatures within 10 F degrees of the maximum for 365 hot summer days from the upper Midwestern United States are compared with those at Yuma, Arizona, and found to be similar. On only 30 percent of the observed days does the daily maximum temperature as recorded on a maximum thermometer appear in the hourly records. The hourly maximum temperature rarely persists for longer than 3 hours, while at 10 F degrees below the maximum the average duration is approximately 10 hours.

RELATIONSHIP OF HOURLY DURATIONS TO THE DAILY MAXIMUM TEMPERATURE

Introduction

In the midwestern United States nearly every summer has spells of hot weather, periods that are significantly warmer than normal for the locality in which they occur. Sometimes the temperature may be abnormally high and approach or even exceed the previous high temperature recorded at a particular weather station. Each day the temperature goes through its diurnal cycle with a minimum usually in the early morning hours, after which it rises until a maximum is reached, usually between two and four o'clock in the afternoon.

The durations of temperature at 1 F degree intervals below the maximum of each day were counted for a sample of hot days and a relationship was established. Court (1952), in a similar study of two desert stations,* found that temperatures stayed close to the maximum for a longer period than had been believed until this time. He also found that cooler days in desert areas tended to follow the same diurnal cycle as the hottest days. No one had made a study of high temperature durations in non-desert areas to determine if the same relationship to the daily maximum existed, or whether it was in some way different from a typical diurnal cycle at a desert station. While maximum temperatures between 120 and 126°F were prevalent in the study by Court, temperatures only 5 F degrees lower (115 - 120°) have been recorded at stations on the Great Plains. This report is a result of a study of stations in the upper Midwest with temperatures exceeding 100°F.

Summer Days with Maximum Temperatures Above 100°F in Upper Midwestern United States

Three hundred sixty-five days with maximum temperatures 100°F or above during the years 1951-1955 were investigated to determine the duration in hours at each successive 1 F° until 10 degrees below the maximum had been reached. The base chosen for the investigation was 100°F because the range of temperature would be about the same as in the earlier study of desert stations, and because a temperature just above body temperature should have significance for studies dealing with man and his reactions to heat.

* The stations studied were Cow Creek (in Death Valley), California, and Andimishk, Iran.

Local climatological data for stations in the upper Midwest were scanned to select those days in which the maximum temperature exceeded 100°F. Year, month, date, and actual temperature were recorded. After the selection of days had been made, the next step was to use the table of hourly temperatures published in the Supplement to Local Climatological Data. The first significant finding was that maximum temperature of the day as recorded on a maximum thermometer and published in the Local Climatological Data for a station may not be recorded in the hourly data as published in the Supplement. On only 114 of the 365 days investigated (31% of the total) did the maximum temperature appear in the hourly records. Of those days on which the maximum did appear in the hourly table, the durations at the maximum varied from 1 to 3 hours. The durations at the maximum are shown in Table I. As the daily maxima increase there is a greater tendency for them not to appear in the hourly data; where it is recorded, the duration of the maximum decreases as the temperature increases. There were no 3-hour durations at 104°F and above, and no 2-hour or 1-hour durations at 109°F and above.

TABLE I

Number of Days Investigated at Each Maximum Temperature
and Hourly Duration at the Maximum

Midwestern Stations							
Temp. of Max. °F	Number of Hours at the Maximum						
	Days	1 hr.	%	2 hr.	%	3 hr.	%
100	60	20	33	4	7	1	1
101	60	12	20	2	3	0	
102	60	14	23	5	8	1	1
103	40	10	25	2	5	2	5
104	40	6	15	6	15	0	
105	40	10	25	4	10	0	
106	20	7	35	0			
107	15	5	33	0			
108	12	1	8	2	17		
109	6	0					
110-115	12	0					
Total	365	85		25		4	

The data in Table I show that the shape of the diurnal curve near the top varies greatly from day to day, but there is a tendency for the curve to be more peaked on the days when the higher maximum temperatures are recorded.

The next step in the investigation consisted of recording the durations at each 1° drop below the maximum of the day. Days were grouped according to their maxima. Thus, days with a maximum of 100°F had their durations recorded at 99, 98, 90°F, whereas for the group with maxima of 105°F durations were recorded at 104, 103, 95°F. As shown in Table I, the number of days investigated at each maximum temperature was not the same. This is because higher temperature maxima are not recorded on as many days nor at as many stations as are the lower maxima.

As there was variation in the length of the durations at the maximum, so was there at each 1° drop below the maximum. This usually amounted to a spread of about 0 to 3 hours at the maximum, 1 to 4 hours at 1° below the maximum, and 2 to 6 hours at 2° below maximum. Occasionally, there would be a very short or an unusually long duration, but the tendency was for the median to be nearer the longer duration. The durations for each category were averaged and converted to minutes for ease of comparison (see Table II).

Summer Days at Yuma, Arizona with Maxima Above 100°F.

As in the Midwest investigation, hourly durations in relation to daily maxima at Yuma, Arizona, were investigated. The study was limited to 20 days at each maximum above 100°F in the period 1951-1955. While maxima were recorded at higher temperatures at Yuma than at Midwest stations, it was not possible to find 20 days with a temperature level of 114° or above in the five years under investigation. Above 106°F in the Midwest, and above 113°F at Yuma, there were fewer recordings and a tendency for the maxima not to be recorded in the hourly observations. Also, the number of occurrences of an hourly observation equal to the daily maximum is much more erratic at Yuma than at the Midwest stations. Maximum temperatures between 100°F and 110°F were recorded in the hourly data about 18% of the time as compared with 31% in the Midwest (Table III).

The data in Table IV for Yuma are comparable to Table II for the Midwestern stations. There is a tendency for durations to be a trifle longer at the Midwest stations, although there are notable exceptions to this generalization. Yuma has the highest average duration at 10° below the maximum, 10 hours at 106°F. However, the tendency for durations to be less at 1° below the higher maxima is very pronounced in the Yuma record. The higher the daily maximum temperature, the less likely is the possibility of recording an hourly temperature at the maximum for the day.

TABLE II

Average Duration of Temperature in Relation to the
Daily Maximum at Midwestern Stations (in minutes)

Max. Temp. of Day	Degrees Below Daily Maximum									
	1	2	3	4	5	6	7	8	9	10
100	110	181	280	323	367	410	451	484	508	554
101	101	166	225	284	344	379	428	457	498	529
102	107	202	260	319	371	414	449	476	518	542
103	109	197	276	330	366	401	432	470	507	540
104	107	179	240	300	335	374	409	435	465	491
105	99	165	248	290	335	387	411	449	470	497
106	99	165	258	321	354	396	432	471	498	531
107	100	188	244	292	328	364	408	424	468	504
108	95	175	235	330	360	390	410	470	475	515
109	130	160	270	320	350	390	440	440	510	510
110	55	130	190	240	295	340	390	410	465	470
111	55	130	190	240	295	340	390	410	465	470
112	55	130	190	240	295	340	390	410	465	470
113	55	130	190	240	295	340	390	410	465	470
114	55	130	190	240	295	340	390	410	465	470
115	55	130	190	240	295	340	390	410	465	470

TABLE III

Number of Days Investigated at Each Maximum Temperature,
with Hourly Duration at the Maximum, at Yuma, Arizona

Temp. of Max. °F	Days	Number of Hours at the Maximum					
		1 hr.	%	2 hr.	%	3 hr.	%
100	20	5	25	2	10		
101	20	7	35	1	5		
102	20	1	5	1	5		
103	20	1	5				
104	20	3	15				
105	20	1	5	2	10		
106	20	5	10	1	5	1	5
107	20	2		1		1	
108	20						
109	20						
110	20	6	30				
111	20						
112	20						
113	20						
114	12						
115	9						
116	5						
117							
118	4						
119							

TABLE IV

Average Duration of Temperature in Relation to the
Daily Maximum at Midwestern Stations (in minutes)

Max. Temp. of Day	Degrees Below Daily Maximum									
	1	2	3	4	5	6	7	8	9	10
100	129	207	282	330	372	396	441	477	513	543
101	114	174	228	288	342	405	429	468	492	507
102	57	174	228	279	327	384	414	447	507	552
103	51	153	210	288	348	387	426	483	516	564
104	60	162	222	282	330	375	426	456	498	519
105	30	111	189	255	348	369	423	429	453	522
106	96	168	285	333	387	417	453	498	549	612
107	84	171	249	303	381	385	444	483	543	549
108	42	120	201	246	279	357	393	432	459	495
109	39	105	213	255	321	363	405	429	459	501
110	36	63	189	237	303	348	375	423	453	510
111	54	132	204	252	312	348	381	426	444	471
112	39	51	135	204	258	285	359	387	429	465
113	33	66	156	231	267	315	345	384	432	465
114	15	70	130	230	260	305	325	375	415	455
115	7	73	120	247	220	240	333	360	367	400
116	30	70	140	264	276	324	348	372	420	444
117										
118	0	30	30	195	210	240	315	270	360	435
119										

Summary

On the hottest summer days (100°F and above) in the upper Midwest, as at Yuma, temperatures on the average tend to remain within 4° of the maximum for 5 hours. At 10° below the maximum the average durations vary from 8 to 10 hours. The higher the maximum temperature the shorter the duration 1 or 2 degrees below the maximum, but a tendency to even out is apparent when temperatures 3 or 4 degrees and down to 10° below the maximum are reached. Neither at Yuma nor at the Midwest stations did durations remain at the maximum for as long as in the desert stations investigated by Court.

There is no difference in the shape of the curves obtained on days with maximum temperatures above 100°F as far down as 10° below the daily maxima, in the upper midwestern part of the United States and at a desert station such as Cow Creek or Andimishk. It would be interesting to see if the pattern changes at stations with lower maxima. Studies of this type from winter and summer months, from arctic and tropical stations, would give a much keener insight to the overall problem of predicting durations from commonly available summarized data.

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